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ABSTRACT

This report summarizes a hearing held on the current state of research facilities at United States universities. The hearing also focused on what role the federal government, universities, and business can play in restoring the university research infrastructure. Part I of the report analyzes the hearing according to the various issues that were raised by witnesses. These issues are: (1) research facilities; (2) research equipment needs; (3) recruitment of young faculty; (4) graduate students; and (5) university-industry relationships. Recommendations that both federal and state governments could employ to address problems related to these issues are also summarized. They include: greater university, government, and private cooperation; establishing new federal and state funding mechanisms; and reviving past programs, such as the National Science Foundation's Graduate Science Facilities Program. Part II provides a summary of the verbal and/or written testimony presented by George A. Keyworth, Charles E. Young, Frank H. T. Rhodes, John D. Silber, and Charles Hess. (JN)

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[COMMITTEE PRINT]

SUMMARY AND ANALYSIS OF HEARING ON "IMPROVING THE RESEARCH INFRASTRUCTURE AT U.S. UNIVERSITIES AND COLLEGES"

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REPORT

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC, July 20, 1984.

To All Members, Committee on Science and Technology:

I am transmitting herewith a summary and analysis prepared by the Committee staff in cooperation with the Congressional Research Service. The summary and analysis reviews the hearing on "Improving the Research Infrastructure at U.S. Universities and Colleges" held by the Committee on Science and Technology in May, 1984. This document was prepared by Michael E. Davey, Analyst in Science and Technology of the Congressional Research Service's Science Policy Research Division, and Karen E. Wieckert, Fellow with the Subcommittee on Science, Research and Technology.

The purpose of the Committee hearing was to familiarize members with the current state of the research enterprise at our universities and colleges. Clearly, the health and vitality of academic research are crucial to our overall strength in science and technology.

The hearing examined many aspects of academic research infrastructure, including; research facilities and equipment, recruitment of faculty and graduate students, and government-university-industry relationships.

This analysis is an excellent distillation of the essence of the Committee's hearing and includes a summary of each witness' testimony. I commend it to your attention.

Sincerely,

DON FUQUA,
Chairman.

LETTER OF SUBMITTAL

CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS,
Washington, D.C., August 3, 1984.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: I am pleased to submit this report entitled, "Summary and Analysis of Hearings on Improving the Research Infrastructure at U.S. Universities and Colleges" prepared at the request of the Committee on Science and Technology.

The report summarizes a hearing held on the current state of research facilities at U.S. universities. The hearing also focused on what role the Federal Government, universities and business can play in restoring the university research infrastructure. The first section of the report analyzes the hearing by the various issues that were raised by the witnesses. The second section of the report contains a summary of each witness' testimony.

The report was prepared by Michael E. Davey, Analyst in Science and Technology, Science Policy Research Division. Production support was provided by Christine Anderson and Kaseem C. Hall, under the supervision of Shirley S. Williams.

We hope that this report will serve the needs of your committee and appreciate the opportunity to perform this challenging assignment.

Sincerely,

GILBERT GUDE,
Director.

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IMPROVING THE RESEARCH INFRASTRUCTURE AT UNITED STATES UNIVERSITIES AND COLLEGES

I. Summary of Hearing by Issue

On May 8, 1984, the House Committee on Science and Technology held a hearing on the current state of research facilities at U.S. universities. The Committee also examined what role the Federal Government, universities and business can play in restoring the university research infrastructure. The hearing was held in response to various studies which have examined some of the past and current problems confronting the overall U.S. university research infrastructure. For example, one such study, conducted by the Association of American Universities concluded that, "the equipment being used in the top-ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories." [1]

A. Research Facilities [2]

The testimony of the various witnesses described the critical problem facing universities in the area of research facilities. Many of the witnesses testified that science and engineering buildings require increasingly complex design because of the type of research equipment they house. Dr. John Silber,[3] President of Boston University, indicated that:

> Scientific and engineering equipment is, for one thing, often very heavy. The buildings that house it must have floors capable of bearing immense weight. Moreover, such equipment usually requires a carefully controlled environment: controlled in its temperature, its air carefully filtered.[4]

The increasing cost of scientific and engineering education means that colleges and universities are confronted with needs for large capital expenditures just as they are faced with declining enrollments. Regarding this dilemma, Dr. Silber made the following observation:

> A private business faced with the need to upgrade its physical facilities has at least the possibility of financing construction by borrowing against future profits. But colleges and universities do not make profits; when financially successful, all they do is avoid deficits. . . . It has been estimated that colleges and universities can finance out of their own resources no more than half the investment in technological infrastructure needed if we are to be able (to) educate the scientists and engineers our country must have.

Dr. Frank Rhodes, President of Cornell University, began his testimony by summarizing the findings of a National Science Foundation (NSF) survey on research facilities. He stated that:

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[1] The Scientific Instrumentation Needs of Research Universities, a report to the National Science Foundation by the Association of American Universities, June 1980, p. 1.

[2] Research facilities are the bricks and mortar (it could include mobile or remote spaces, such as ships, airplanes, aquaculture facilities and monitoring stations) which house and support academic research and research instrumentation.

[3] Due to weather difficulties Dr. Silber was not able to attend the hearing and testify in person. All of his comments are taken from Dr. Silber's prepared statement submitted for the record.

[4] All quotes are from testimony given by witnesses at the Hearing on "Improving the Research Infrastructure at U.S. Universities and Colleges", held by the Committee on Science and Technology, U.S. House of Representatives, May 8, 1984.

A preliminary NSF survey of 25 universities, just released, conservatively estimated that research universities and colleges require $1.3 billion per year to meet accumulated research facilities needs. In FY 1984 the total Federal investment in R & D plant in universities and colleges is projected to be $40 million, and essentially all of these funds are targeted on special purpose user or national facilities.

President Rhodes believes there is now no general reinvestment effort by NSF or any other mission agency aimed at modernizing the infrastructure of our major universities. He concluded his testimony with the following statement: "This is, I must emphasize, the most serious long-range problem facing our research universities."

Dr. Charles Hess, Dean, College of Agriculture and Environmental Science, University of California at Davis, agreed with Dr. Rhodes:

Space is also a critical limiting factor in the research infrastructure at many universities, both in terms of quantity and quality. An inventory conducted by the USDA in 1978 showed that there was a shortage of 1,110 scientist spaces equivalent to 15 percent of the scientific population in State Agricultural Experiment Stations.

Dean Hess continued by speaking of the reluctance to fund the construction of research facilities:

There has been a great reluctance by Federal and State government, the private sector and foundations to become involved in the business of bricks and mortar. State appropriations often have been targeted to alterations or modifications to meet government regulations for fire, occupational, and seismic safety and for access for the handicapped. State funding for new facilities is driven more by student numbers than research needs.

Chancellor Dr. Charles E. Young, from the University of California at Los Angeles, noted that when resources are scarce, schools defer the renovation of facilities thinking that a delay of one or two years will not hurt. But, the delays have gone on for years. Consequently, "Inadequate facilities and outdated equipment are a direct threat, across the country, to the quality of instructional and research programs."

Dr. Young provided examples of the enormous sums needed for the updating and construction of facilities throughout the University of California system:

We undertook a careful and realistic review of our need for facilities funding over the next decade. What we learned is that we have an enormous problem. The university will need more than $4 billion for facilities renovation and construction in the next decade.

This breaks down into several major components:

—$1.6 billion will be needed for construction or major renovation of basic academic facilities housing instructional and research programs, libraries, public service programs, hospitals and clinics, and administration.

—$900 million will be needed to keep existing facilities functioning safely and efficiently, including corrections for seismic safety. About $500 million will be needed for self-supporting enterprises such as student and faculty housing and student activities.

—And, in addition, we need nearly $1 billion of additional operating budget funds to bring the level of routine building maintenance up to standard and to eliminate a large backlog of deferred maintenance projects.

Dr. Rhodes testified that Cornell's facility needs will also be expensive:

In areas where we have great scientific competence, we have identified more than $100 million in facilities needs. These areas include biotechnology, plant and molecular biology, microbiology, animal reproductive biology, veterinary medicine, astronomical and atmospheric sciences, electrical engineering, material

sciences, computer simulation and theoretical computations, social and economic sciences, computer sciences, and manufacturing technology.

Chancellor Young testified that although enrollment increases are no longer forcing the need for new facilities, there are other reasons why needs are so acute:

First, obviously, existing buildings deteriorate. Periodically, they need paint, light fixtures, floor coverings, roofs, and other replacements. A second kind of facilities need occurs because the university's academic programs must change over time in order to keep pace with the latest advances in each discipline. . . . For example, rapid technological development in the biological sciences has required not only new kinds of equipment but also new kinds of building systems. Enrollment shifts among disciplines are a third factor in facilities needs. Enrollments in engineering and computer science courses have increased sharply since 1975. At the University of California, historical shortages of space generate a fourth need. A fifth need, and that is to update facilities continually in order to meet changing code requirements and standards for health and safety, including seismic safety.

Dr. Young also estimated the national cost for facilities needs.

Because California has about 10 percent of the country's population and receives about 10 percent of Federal research grants, we could conservatively estimate the national need at 10 times $4 billion—or $40 billion. The obvious question is, where will that money come from?

Dr. George Keyworth, Science Advisor to the President, noted that the allocation for capital equipment has to be part of the grant process. Dr. Keyworth warned that in allocating large capital commitments for research facilities:

. . . we have frequently failed to recognize that a realistic assessment of the operating funds is essential to utilizing that facility.

We have, for example, built gigantic accelerators in this country for sums of hundreds of millions of dollars, and then found ourselves using them at 30 percent of the time that is available because of operating constraints.

Dr. Keyworth concluded his remarks by noting he believes that the states have been more innovative when funding capital development. However, he believes future success will require a key partnership:

Interesting enough, some of the States have been extremely innovative, in fact, I would even go so far as to say somewhat more innovative than we in the Federal Government. I think that there is perhaps an important lesson there but, again, I think the States clearly will be part of the Government-industry-academia partnership, and I think we should look towards this as a means of bringing the individual regions of our country closer to the allocation process.

B. Research Equipment Needs

The witnesses testified that many of our leading research universities are suffering from a lack of modern research equipment. They indicated that universities are often unable to provide their faculty or students with modern equipment needed to carry out state-of-the-art education and research programs.

These problems were noted by Dr. Charles Young, from the University of California at Los Angeles:

The shortage of modern equipment has caused academic departments to redesign courses around less effective and outdated equipment, to eliminate experiments and exercises from laboratory sessions, or to reduce the length of laboratory sessions in order to meet student demand. In fields such as biochemistry and electrical engineering, many students have to watch demonstrations instead of getting hands-on experience with the equipment.

Dr. Young pointed out that many instrumentation shortages are in areas critical to our economic future:

In short, in fields which are most important to the nation's future economic well being, students are being denied the opportunity to understand the most recent developments in their field and the quality of academic programs is being undermined.

Dr. Charles Hess, University of California at Davis, summarized some of the findings of the 1980 Association of American Universities study:

. . . capital expenditures for instrumentation doubled in the five-year period from 1975 to 1979. Even with the increased expenditure, the median age of instrumentation at universities was twice that of industrial laboratories.

Dean Hess pointed out to the Committee just how costly it is to establish one biotechnology research position:

To recruit and adequately accommodate one scientist in this area of research costs an average of $125,000 for equipment alone. This figure does not include the cost of renovation of laboratories, which ranges from $30,000 to $60,000.

Dr. Rhodes, from Cornell, also emphasized this point:

New faculty members need laboratories with new capabilities and new, often different, kinds of equipment. Typically, we must find between $100,000 and $300,000 to equip a laboratory for a new faculty member. We don't always succeed. When you realize that we may appoint 20 or more young scientists a year you can understand why.

Dean Hess testified about a recent Department of Defense study:

DOD estimates that $1.5 to $2.0 billion would be required to elevate qualified academic laboratories to "world class" status in instrumentation. In response to the first year of a five-year $150 million program, DOD received 2,478 proposals totaling $645 million. Two hundred and four awards were made with each averaging $148,000. That represents an award rate of eight percent and a funding level four percent of the amount requested.

President Rhodes, of Cornell, provided further evidence of research equipment needs from a recently released NSF survey of research instrumentation systems in computer and physical sciences and engineering:

One fourth of the 1982 research equipment inventory in these fields, which had an aggregate purchase price of $904 million, is obsolete and no longer in research use.

Only 16 percent of all academic research equipment inventoried is state-of-the-art.

More than 90 percent of departmental chairpersons surveyed reported that the lack of equipment inhibited the conduct of critical research.

31 percent of all instrument systems in use in 1982 were more than ten years old.

Contrary to the expectations of some, university researchers do share equipment at significant levels. Each instrument system in service in 1982 was used by a median of seven researchers. The median number using each piece of computer sciences equipment was 25 researchers.

43 percent of the chairpersons rated the quality of support services (e.g., machine shop, electronics shop, etc.) as "insufficient" (40 percent) or "non-existent" (6 percent).

NSF is the leading Federal sponsor of research equipment purchases in the physical and computer sciences, providing about 52 percent of Federal support in these two fields.

DOD is the primary Federal funding agency in engineering, accounting for 45 percent of the federally financed engineering research equipment.

Nonfederal sources play an important role. In 1982, 78 percent of computer sciences instrument systems, 64 percent of engineering systems and 52 percent of physical sciences instrument systems were not federally funded in their entirety. Universities' own funds accounted for at least 70 percent of the non-Federal funds used for equipment in each of these three fields.

Industry funds accounted for 10 percent of non-Federal research equipment purchases.

Dr. George Keyworth, Science Advisor to the President, indicated that deficiencies, such as those pointed out by the NSF survey, present specific problems to both teachers and students:

These deficiencies directly affect the ability of the university scientist to conduct front-line research, they hamper the ability of students to learn the newest technologies, and they make it more difficult for universities to compete with industry for faculty in areas that are strongly dependent on the use of modern research equipment.

Dr. Keyworth testified that instrumentation problems have many causes. The rate of technological progress, for example, quickly renders scientific instrumentation obsolete. He stated:

For that reason we have to recognize its not only an acute problem today, but as a continuing problem from now on. For that reason there can be no such thing as a one-shot solution. The Federal Government, which has been the primary source of university instrumentation for the past forty years, clearly has a responsibility.

And, Dr. Keyworth indicated that the Administration has lived up to its responsibility in this area:

In fiscal year 1984 and 1985 we expect a total of more than $800 million in Federal funds to be applied to high-priority instrumentation needs in universities. There have been some specific instrumentation programs established in Federal agencies, and those are particularly useful in providing major instrumentation that will be available to a large number of users.

Although Dr. Rhodes, Cornell University, praised the Administration's funding efforts, he pointed out that universities cannot acquire a major new piece of equipment through these types of funding programs:

You can't, for example, get a major new piece of instrumentation costing, let's say, $1.5 million, on a small research project of $300,000. The National Science Foundation and other agencies won't generally accept that need, and it's the larger scale instrumentation where we face major problems, instrumentation shared by dozens of scientists and engineers.

Dr. Rhodes concluded his remarks by indicating that this presents special problems because, "The fields in which we are engaged are changing so rapidly that equipment has a more and more limited useful life."

C. Recruiting Young Faculty

Some of the witnesses testified that outdated facilities and research equipment have made it extremely difficult to recruit new faculty. This recruiting problem has developed because young scientists believe that the research environment in the private sector is more attractive than in the universities.

Dr. Keyworth, the Science Advisor to the President, reinforced this when discussing the shortage of engineering faculty:

This shortage is primarily caused by two countervailing trends: the improving attractions of pursuing research careers in industry—and the declining quality of life even in many leading universities.

Dr. Keyworth continued by describing what the Reagan Administration has done to help universities with their recruiting efforts:

We took direct steps last year to address this problem with the Presidential Young Investigator Awards Program. That program, which was strongly en-

dorsed by this committee when it was introduced last year, has now been received with tremendous enthusiasm by both academia and industry. As the numbers of young faculty in this program grows to its target level of 1,000, we expect to be able to correct and head off some of the most serious faculty shortages in critical scientific and engineering fields.

Dr. Rhodes, President of Cornell University, commended the Presidential Young Investigator initiative, but believes more must be done:

. . . the support of young faculty ought not to be the sole responsibility of the National Science Foundation. We urge the Committee to exercise its leadership to encourage the appropriate committees of the House to add small initiatives for this purpose to the research programs of DOE, NASA, USDA, DOD and NIH.

Another concern related to faculty needs was raised by Dr. Charles Hess from the University of California at Davis. Dr. Hess testified that the lack of qualified laboratory technicians also hurts the research infrastructure:

Technicians are an invaluable asset in a faculty member's laboratory for the operation and maintenance of equipment, and to continue experiments for faculty when they must be in class or meeting their other university responsibilities.

D. Graduate Students

Similar to the problem of attracting younger faculty is the universities inability to attract adequate numbers of graduate students. Declining Federal support for graduate education and increased opportunities for engineering students with B.S. degrees have convinced many students to seek employment and postpone their graduate school plans.

Dean Hess, from the University of California at Davis, addressed this problem in his testimony:

This is particularly true in engineering, but it is also the case in the basic sciences, including plant biology. In the case of engineering, opportunities in industry for B.S. graduates are great enough that many bright, young people are choosing to go directly into industry rather than pursue graduate study or careers in the university.

In his testimony, Dr. Frank Rhodes, President of Cornell University, detailed the decline of federally funded fellowships which have been an important determining factor in the careers of numerous researchers who have contributed to great scientific advancements:

But now we face a serious shortage of graduate students in certain fields. For 15 years, Federal support for graduate education has been substantially reduced. The number of federally funded graduate fellowships in the physical sciences and engineering has declined from 51,000 in 1968 to about 1500 today. In the face of sharply increasing international competition, critical national needs served by graduate education are going unmet.

Dr. Rhodes contended that the Administration has targeted very narrow areas for increased support in graduate education. "The present Administration proposes small, highly targeted increases in university research and development, most notably in the areas perceived to be of closest significance to the national defense."

Dr. Rhodes concludes his statement by noting that some hopeful signs have been seen in agencies such as NSF. "Moreover, after almost a decade of neglect, additional steps to strengthen the NSF graduate fellowship programs are proposed."

E. University-Industry Relations

A final issue discussed by some of the witnesses was what role the private sector can play to improve the university research infrastruc-

ture. Although the witnesses agreed that industrial support for reviving their research capabilities would not be significant, industry's participation is crucial for its overall success.

Dr. Frank Rhodes, President of Cornell, pointed out in his testimony:

> The magnitude of industrial support is now about 3 percent of total university research expenditures; few experts see it ever rising to more than 8–10 percent. . . . Still, the magnitude of recent developments constitutes significant change. In every year since 1970, industry funding of university-based research, in constant dollars, has increased. Total funding doubled between 1970 and 1983; it increased by 11 percent in 1980–81 alone.

Dr. John R. Silber, President of Boston University, supported Dr. Rhodes' position in his testimony to the Committee:

> It is obvious that the Federal Government should not be asked to solve the crisis in infrastructure by itself. . . . The State Governments, whose economies will also benefit, must also help. And private industry, which benefits as directly as any member of the partnership, must contribute. At Boston University, we have been fortunate in receiving millions of dollars for our Science Center from such corporations as Digital Equipment, IBM, Data General, and the John Hancock Mutual Insurance Company.

Dr. George Keyworth, Science Advisor to the President, testified that the private sector has an important role to play in strengthening the university infrastructure:

> As you know, Federal programs, State and local government efforts, and industrial initiatives, both separately and in growing partnership, have gone a long way over the past few years in strengthening those areas of university research and training with the greatest potential for contributing to our needs.

Dr. Keyworth believes that newly created programs, by this Administration, will stimulate further cooperation. An example of this is:

> . . . NSF's new program to establish university engineering research centers to stimulate interdisciplinary research and training. These centers will also provide a means for greater industrial participation in improving the university environment, because the center programs are expected to have extensive collaboration between industry and academia.

F. Proposed Recommendations By Witnesses

Following their review of the infrastructure problem, several of the witnesses made various recommendations that both Federal and State governments could employ to address these problems. Their recommendations included such ideas as: greater university, government and private cooperation; establishing new Federal and State funding mechanisms; and reviving past programs, such as NSF's Graduate Science Facilities Program.

Dr. Charles Hess, Dean, College of Agriculture and Environmental Sciences, University of California at Davis, referred to the NSF program in his testimony:

> Another approach to meet the needs for both equipment and research space is to reinstitute the Graduate Science Facilities Program in NSF. From 1960 to 1972, the National Science Foundation conducted institutional programs to strengthen research and education in U.S. college and universities. In contrast with other NSF programs, which are generally geared toward individual research, there were institutional programs targeted to improve the quality of academic science on a scale at least as broad as a department.

Although Dr. Hess supports NSF's and DOD's current efforts to improve university instrumentation needs, he believes their efforts are focused on the individual investigator, rather than developing laboratories:

The DOD program is designed to fund large items of equipment ($50,000 or more) used by a number of scientists and NSF grants to individual investigators are not intended to establish laboratories.

Dr. Charles Young, Chancellor, University of California at Los Angeles, testified that at his school they had reached some important conclusions regarding funding for university infrastructure:

We believe that the nation's universities must do three things: one, use existing resources as effectively as possible; two, develop new sources of funds; and three, reconsider traditional assumptions about responsibilities for capital development.

Dr. Young, also indicated that Federal and State support for capital projects must be renewed, if the universities are to succeed in meeting this challenge. He noted:

Between 1978 and 1981, non-governmental funds provided an average of 77 percent of the university's capital expenditures, State funds just 22 percent, and Federal contributions 1 percent. If funding continues at the level of the past five years, less than 20 percent of the necessary funding will be forthcoming.

Dr. John Silber, President, Boston University, supported the recommendation for greater Federal support:

The Federal Government should regard the nation's technological infrastructure with the same attention it has paid our transportation infrastructure. The laboratories and classrooms needed for education and research in science and engineering are a national need at least as important as our highways and bridges.

Dr. George Keyworth, Science Advisor to the President, indicated that he believes it is time for the Federal Government to take a fresh look at methods for improving relations between mission agencies and the universities. Consequently, Dr. Keyworth has asked the White House Science Council to undertake a study which would examine the following problems:

—the Federal Government's role in ensuring a productive research environment, including the nagging problem of indirect costs . . .;
—the effects on research productivity of the uncertainties and red tape involved in funding;
—the problem of university physical facilities and instrumentation;
—the problem of increased university interaction with industry . . . how to maximize benefits . . . (and) minimize risks of compromising the research environment.

Chancellor Young also suggested some mechanisms that Federal and State governments could employ to address these national priorities:

For example, facilities grants could be tied to research funding . . . To address this problem, funds for facilities could be granted in connection with the funding of research programs—maybe tied to specific kinds of research projects in science and high technology. As another approach (mentioned by Dr. Silber) universities could be included in programs to renew the nation's (overall) infrastructure . . . Other possibilities include various partnerships with the states in ways that leverage state funds—perhaps through matching grants. Tax incentives which encourage business and industry contributions would be another useful approach.

Dr. Silber, Boston University, pointed out that the Federal Government should not hesitate to provide support for both the "public" and "private" universities:

We speak of "public" and "private" colleges and universities, and it is sometimes asked why the taxpayer should subsidize private institutions. But the fact is that the colleges and universities of the independent sector are no more private than those of the state sector. They are open to the public, educate the members of the public, and conduct research in the public interest.

II. Summary of Hearing by Witness

This section presents a summary of the testimony of each witness who appeared before the committee. In all cases the following abstract is a staff prepared summary of the verbal and written testimony presented.

The first witness to testify was George A. Keyworth, Science Advisor to the President, and Director, Office of Science and Technology Policy, Executive Office of the President. Dr. Keyworth began his testimony by stating that our Nation's universities are one of the most precious resources this country has. He continued by noting:

> Mr. Chairman, there can be no disagreement that the public interest requires a healthy and stimulating atmosphere for both research and education in our universities and colleges. This is a responsibility that cuts across all of society, because all of society benefits from healthy universities.

Dr. Keyworth testified that the Administration policies have helped strengthen the universities' capabilities in the areas of research and training. He indicated that today universities are conducting more basic research than any other institutions in our society:

> And as I pointed out several months ago to this committee—with the President's FY 1985 budget request we're looking at a *real* increase, beyond mere inflation, of more than 25 percent over the past four years in Federal support for basic research in universities and colleges.

Dr. Keyworth further testified that, until the Mansfield Amendment,[5] DOD was one of the stronger and most imaginative supporters of university research. According to Dr. Keyworth, many of the Nation's best research universities—MIT, Caltech, and others—owe their strong research capabilities to DOD's earlier programs. Since the Mansfield restrictions no longer exist, Keyworth hopes DOD can play a more significant role in basic university research. He also recognized that leading civilian mission agencies withdrew their support for university-based R & D in the 1970s:

> With the exception of the National Science Foundation and the National Institutes of Health, during the 1970s the major R & D agencies—DOD, DOE, NASA—diverted research funding away from universities to their own laboratories or to industry.

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[5] Mansfield Amendment: After World War II, the DOD, primarily through the office of Naval Research, supported large amounts of basic research. Even after the establishment of the National Science Foundation, the DOD continued to fund basic research. Consequently, in 1969, Congress passed the "Mansfield Amendment", to the fiscal year 1970 military procurement authorization (P.L. 91-121, section 203), which prohibited DOD from supporting research not having "a direct and apparent relationship to a specific military function or operation."

The following year Congress passed the "modified Mansfield Amendment" to fiscal year 1971 military procurement authorization (P.L. 91-441), which prohibited funds authorized by that "or any other Act" from being used to conduct R&D unless the Secretary of Defense determines the existence "of a potential relationship to a military function or operation."

The primary result of the Mansfield Amendment has been to temper the relationship between DOD and the Nation's colleges and universities. For example, in 1982-83 DOD funded only about 8 percent of basic research and about 9 percent of applied research performed by colleges and universities.

Dr. Keyworth continued by noting that the deterioration of research instrumentation has been the subject of various studies. He then pointed out some of the findings of a preliminary NSF survey on instrumentation:

In a recent NSF survey, officials of 43 universities and colleges classified 25 percent of their research equipment as obsolete. In fact of all academic research equipment in use in 1982, only 16 percent was characterized as being "state of the art."

According to the Science Advisor, the deterioration of university research facilities was due to several factors, not the least which is the pace of technological change. Such change quickly renders scientific instrumentation obsolete. Further, Dr. Keyworth emphasized that the pace of technological change will remain an acute problem, which means a oneshot solution will not be adequate. Dr. Keyworth stated that it is very difficult to get a good idea of just what the laboratory needs of the universities are. An ad hoc interagency steering committee was formed by NSF in November of 1985 to conduct a study of the university research facilities needs. This study will be completed in February of 1985.

Dr. Keyworth pointed out that the White House Science Council is also engaged in a study to determine whether there could be a more productive relationship between mission agencies and universities. The White House study will look at several areas, including, "the Federal Government's role in ensuring a productive research environment . . . including the nagging problem of indirect costs."

Dr. Keyworth noted that the continued increase in university indirect costs for conducting research is one of the most frustrating issues for the Science Council. Other areas the Council will focus its study on include:

The effects on research productivity of the uncertainties and red tape involved in funding;

The problem of university facilities and instrumentation;

Ways to encourage foreign graduate students to stay in this country once they have completed their studies;

Ways to increase interactions between universities and industry.

According to Dr. Keyworth, the outcomes of this study will play an important role in determining the approaches we might propose to take in solving our infrastructure problems.

Charles E. Young, Chancellor of the Los Angeles campus of the University of California, began his presentation by stating that educational facilities are in despair. "Inadequate facilities and outdated equipment are a direct threat, across the country, to the quality of instructural research programs."

Dr. Young illustrated the problem by stating that the University of California system will need a total of more than $4 billion in the next decade for construction and renovation, to keep existing facilities functioning safely for student and faculty housing, student activities and for maintenance projects.

In giving the reasons for renewal funding, Chancellor Young outlined five kinds of needs that have developed:

First, existing buildings require routine maintenance, paint, new roofs, light fixtures, etc.;

Second, academic programs must change to keep pace with advances in the disciplines;

Third, enrollment shifts among disciplines;
Fourth, historical shortages of space within the university;
Fifth, updating of facilities to meet state requirements for health and safety.

Dr. Young pointed out that many of the same reasons also apply to instrumentation renewal needs for instruction and research. Due to outdated equipment, courses have been redesigned, experiments eliminated, and lab sessions shortened. He also indicated that needed research cannot take place:

In short, in fields which are most important to the nation's future economic well being, students are being denied the opportunity to understand the most recent developments in their field and the quality of academic programs is being undermined.

Dr. Young continued by saying that funds are also needed for computers in all disciplines and that the demand is great for computer instruction and use.

Chancellor Young pointed out the important role universities play in the high technology industry and thus the economy of the United States:

We provide the research which leads to technological advances and we train the workforce of engineers, computer scientists, and biologists. Improving funding for facilities and instrumentation is needed to strengthen the capability of universities to contribute to the nation's long-term economic capability.

Based on the funding needs of the University of California, Dr. Young estimates that the Nation will need $40 billion to rebuild its university facilities. To meet this need, he recommended that universities use existing resources effectively, develop new funding sources, and "reconsider traditional assumptions about responsibilities for capital development." Chancellor Young called for nontraditional approaches, mixed funding resources, and long-term commitments from states, business, industry, private donors, universities and students, and the Federal Government.

Dr. Young testified that prior to 1964, Federal funds were directed to research activities. From 1964–1980, Federal funds accommodated expanding enrollments and the need for health care professionals. Since 1977, however, few Federal or State funds were available for capital projects:

Between 1978 and 1981, non-governmental funds provided an average of 77 percent of the university's capital expenditures, State funds just 22 percent, and Federal contributions 1 percent.

Finally, Dr. Young outlined several possible approaches for greater Federal funding for higher education's facilities and instrumentation needs. These approaches included tying facilities grants to research funding or creating a special facilities program through NSF. Chancellor Young also mentioned that programs to renew the Nation's infrastructure could include the universities. Other approaches included matching grants, tax incentives encouraging business and industry contributions, and continuing Federal subsidy programs.

Dr. Young concluded by saying:

These are suggestions only—meant as a help in starting discussion on a national problem that requires a joint effort for solution. Higher education and the Federal Government have worked together before, and now must again, to address problems which could affect the future health of this country.

Dr. Frank H. T. Rhodes, President, Cornell University, testified on behalf of the Association of American Universities, National Association of State Universities and Land-Grant Colleges, American Council on Education, Association of Graduate Schools and the Council of Graduate Schools.

Dr. Rhodes opened his testimony by stating that the research and development base which this Nation created remains the strongest and most productive in the world. Nevertheless, he went on to say:

> In spite of a recent increase in research and development expenditures, the basic research components of those increases have been modest, and we now face serious problems in the nation's basic research effort.

In the area of graduate education, President Rhodes testified that our graduate schools provide talented individuals with the knowledge, technical skills and economic strength we need to survive. However, one of the main mechanisms for supplying those graduate students has been seriously crippled:

> But we now face a serious shortage of graduate students in certain fields. For 15 years, Federal support for graduate education has been substantially reduced. The number of federally funded graduate fellowships in the physical sciences and engineering has declined from 51,000 in 1968 to about 1,500 today.

Dr. Rhodes described how after almost a decade of neglect, the NSF has begun to strengthen its graduate fellowship programs. Other programs, such as the new graduate fellowship program at the Office of Naval Research, is an excellent model that mission agencies, such as NASA, NIH, DOE and DOD, could implement. This ONR program offers students competitive three-year fellowships with stipends of $13,000, plus full tuition and a $2,000 research award to the host department. Such a program in the major mission agencies, could provide a total of 1,500 to 2,000 additional awards annually.

Linked closely to the needs of graduate students are the increasing challenges associated with recruiting young faculty. Dr. Rhodes praised the NSF's Young Presidential Investigator Awards Program aimed at increasing the number of young faculty. However, President Rhodes continued with the following statement:

> But the support of young faculty ought not be the sole responsibility of the National Science Foundation. We urge the Committees to exercise its leadership to encourage the appropriate committees of the House to add small initiatives for this purpose to the research programs of DOE, NASA, DOD and NIH.

Dr. Rhodes then turned his attention to the problem of research facilities by quoting the findings of a recently released NSF survey on research instrumentation systems in computer and physical sciences and engineering. The report produced the following findings:

> —One-fourth of the research equipment inventoried in 1982 was obsolete;
> —Only 16 percent of all academic research equipment inventoried is state-of-the-art;
> —90 percent of department chairpersons said they lacked equipment for critical research;
> —Instrument systems in service in 1982 was used by a median of seven researchers . . . in computer sciences the median was 25 researchers;
> —46 percent of the chairpersons rated the quality of support services as insufficient.

Dr. Rhodes quoted the results of another, preliminary survey of 25 institutions just released by NSF. According to this survey, research universities and colleges will need $1.3 billion per year to meet accu-

mulated research facilities needs. In FY 1984 total Federal investment in R&D plant facilities is estimated to be $40 million. According to Dr. Rhodes, such levels of funding are not adequate to meet our needs:

> Just as several agencies have begun to address the research equipment, we urge the committee to ask them also to achieve a shared assessment of the facilities problem by field and to fashion a comprehensive government-wide approach to address it.

President Rhodes concluded by stating that only a shared long-term reinvestment plan and funding strategy will provide the breadth and concentration of resources necessary to address these needs.

Dr. Rhodes indicated that Cornell's Materials Science Center has made capital equipment one of its highest priorities. The Center usually allocates 15 to 20 percent of its annual budget to capital equipment. Despite this, he testified; "it is not closing the gap in comparison with the equipment resources available in major industrial and government laboratories."

According to President Rhodes, the situation with respect to facilities is even more acute. He pointed out that in areas where Cornell has the greatest scientific competence, they have identified over $100 million in facilities needs, but are uncertain about where this money will come from.

Another area addressed by Dr. Rhodes was the problem of increased overhead costs. He spoke out against the Department of Health and Human Services' proposal to cut reimbursement of indirect research costs by ten percent. He stated that indirect costs had risen for a number of reasons: the artificial capping of costs until 1980, inflation, the cost of compliance with government regulations, the changing nature of research, the fact that research costs once paid for by universities now fall under indirect costs, and the improved identification of these costs due to better management.

President Rhodes closed his testimony by noting that industrial support for university research is extremely important. He testified that the Economic Recovery Tax Act of 1981 had stimulated industrial support for university-based research. Dr. Rhodes concluded his remarks on the Tax Act with the following statement:

> This appears to be having a very significant impact, in certain corporations. It ought to be strengthened to provide for the donation of instructional equipment, for equipment previously used by the donor for less than three years, and to remove present ambiguities over the donation of computer software.

Dr. John D. Silber, President of Boston University, opened his prepared statement by noting that the Nation is facing a crisis on its campuses. The crisis relates to the ability of our colleges and universities to provide the physical facilities in which to educate scientists and engineers and to carry on research. President Silber indicated that:

> These facilities are different in kind from those needed to educate the great majority of students. Science and engineering buildings require increasingly complex and expensive equipment, and because that equipment is itself highly specialized, the buildings themselves must be specialized.

Further, Dr. Silber testified that the need for more scientists and engineers and research facilities comes at a time when universities are facing an uncertain future because of declining enrollments. They are faced with difficulties in maintaining their technological infrastructure because, unlike the private sector, the universities do not make

profits to finance such needs. Dr. Silber illustrated this problem with the following statement:

> It has been estimated that colleges and universities can finance out of their own resources no more than half the investment in technological infrastructure needed if we are to be able to educate the scientists and engineers our country must have.

President Silber indicated that universities are divided into haves and have-nots. In the independent sector, which comprises 1500 institutions, a mere 35 have approximately 90 percent of the total endowment. Some of these institutions have endowments of up to $60,000 per student.

The "have-nots" according to Dr. Silber, have the most serious problem because they have the smallest financial base from which to invest. For example, Boston University has an endowment of $3,000 per student, "which gives us no more than $300 a year in endowment income per student—a derisory sum."

President Silber testified that there are dozens of have-not universities around the country that have a strong commitment to quality education:

> Like Boston University, they have extended themselves to the breaking point in the interests of technological education for the nation. If in an era of declining enrollments, which nationally will, by 1992, be 25 percent lower, these institutions are required to make the full investment required in infrastructure by themselves, many will go bankrupt.

Below the top 20 to 35 schools, Dr. Silber stated that the next 50 institutions, of which Boston University is a member, are facing needs of $75 million each, or a total of $3.75 billion. This he indicated is a very conservative estimate. Further, Dr. Silber stated that the "have nots" will play a crucial role in providing the expertise the Nation will need in science and technology, since the "have" universities do not possess the capacity to meet the Nation's needs.

President Silber then turned his attention to the need for a partnership between the universities and the private sector. He noted that the private sector, which benefits greatly from cooperative efforts with the universities, must also continue to contribute to rebuilding our infrastructure.

Although the Federal Government should not be expected to solve these problems alone, Dr. Silber believes it has a crucial role to play. He testified that:

> . . . the Federal Government should regard the nation's technological infrastructure with the same attention it has paid our transportation infrastructure. The laboratories and classrooms . . . are a national need at least as important as our highways and bridges . . . it is from such laboratories and classrooms that will come improved methods for building roads and bridges. . . .

President Silber also testified that Congress should not differentiate between "public" and "private" colleges and universities in their funding. He stated that the independent schools are no more private than those of the state sector, because they are open to the public and conduct research in the public interest.

Dr. Silber closed his testimony by indicating that resources necessary to conduct research and education at the cutting edge of science and

technology should not be limited to a few institutions that developed research capacity in the 1950s:

An adequate funded program of grants for laboratory and classrooms construction would be a major opportunity for the Congress to invest tax dollars in a manner that would guarantee the taxpayers a generous return on their investment.

Dr. Charles Hess, Dean, Colleges of Agricultural and Environmental Sciences, University of California at Davis, testified about the limiting factors challenging the research infrastructure at U.S. universities and some options available for meeting the challenges.

The first factor Dean Hess mentioned was that even though capital expenditures doubled from 1975–1979, the median age of university instrumentation was twice that of industrial labs. He noted that: "It is vital that our students have the training and the opportunity to conduct research with equipment of at least equal quality if they are going to be effective in the private sector." Dr. Hess stated that the Department of Defense has estimated that $1.5 to $2.0 billion would be needed to bring qualified academic labs to "world class" status.

A second critical factor outlined by Dean Hess is the quantity and quality of space. He stated that many funding sources are reluctant to become involved in construction of facilities, and that State funds are more often determined by student numbers and not research needs.

The third factor, according to Dr. Hess, is the support personnel; the technicians that are needed to operate and maintain equipment and monitor experiments.

The ability to attract graduate students was the fourth critical factor mentioned by Dr. Hess. Especially in engineering, industrial opportunities for B.S. graduates are attractive enough that many students do not stay at the universities for graduate study or careers.

Dean Hess also presented some options for meeting these problems. First, he encouraged support for the instrumentation programs of the Department of Defense and the National Science Foundation. However, as neither of these programs can help to equip entire laboratories for new faculty, Dr. Hess suggested using the Presidential Young Investigator Awards Program as a model and expanding it to meet that need.

Dean Hess also suggested reinstating the Graduate Science Facilities Program in the NSF which worked to improve the quality of academic science and resulted in purchases of general purpose laboratory equipment and new construction. Dr. Hess feels other agencies should implement similar programs.

Next Dr. Hess stressed that universities must ensure that equipment is used effectively—not only by the university's own faculty—but also by other university and private sector scientists.

Dr. Hess mentioned an Office of Technology Assessment study which suggested that Congress increase funding for USDA, NIH and NSF graduate and postdoctoral training grants in biotechnology. He urged that this approach be expanded to all areas of science and engineering where trained personnel are needed.

Dean Hess spoke out against the recent efforts to seek funding for instrumentation and facility needs within the political arena.

The desperate need for facilities has led some universities to make "end runs" to Congress much to the concern and dismay of the scientific community. A program I just mentioned would give universities a viable alternative and would provide peer evaluation to help ensure that the best investment is made with public and private funds.

Dean Hess concluded by turning his attention to the problem of transferring research findings to the appropriate user. He stated:

. . . we need to conduct research and develop policy for improved methods of handling and transferring scientific information. The translation should be multidisciplinary and problem-focused.

He mentioned that the Cooperative Extention Service program has worked well in disseminating research findings between researchers and potential users.

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